Bureau of Mines
Information Circular 7824

SPODUMENE--MAJOR SOURCE OF LITHIUM

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SPODUMENE - MAJOR SOURCE OF LITHIUM

by

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SUMMARY AND INTRODUCTION

Domestic production of lithium minerals, source of the lightest metallic element, has increased from an average of 1,327 short tons of concentrate in the 1935-39 period to approximately 37,830 short tons in 1954. This rather phenomenal growth in production and use reflects growing industrial interest in the metal and its salts.

This information circular has been prepared to summarize for the casual technical reader the reserve, mining, processing, and consumption situation pertaining to the mineral spodumene - the principal source of lithium. A relatively complete bibliography is included for those who may need more detailed information.

The principal known domestic reserves of spodumene ($LiAlSi_2O_6$) are in North Carolina and in South Dakota. Domestic reserves of the mineral are considered to be quite large.

Three firms, 2 domestic and 1 Canadian, produce the bulk of the United States supply of spodumene. Foote Mineral Co. and Maywood Chemical Co. produce their own raw materials, and each produces lithium compounds. Quebec Lithium Co. produces the spodumene that the Lithium Corp. of America now uses to make lithium compounds.

Spodumene is recovered by heavy-medium separation, flotation, or handpicking. It is processed by roasting the mineral or concentrate with either an alkali or an acid, subsequently water-leaching the soluble lithium salt, and precipitating or reacting the leached salt with other materials to form various lithium compounds.

Lithium is used at present almost entirely in the form of its various compounds. Major uses of the compounds are in pharmaceuticals, storage batteries, air conditioning, lubricating greases, brazing compounds, and ceramics and for various strategic purposes.

HISTORY

Although the element lithium was discovered nearly 150 years ago and is now known to be widely distributed in the rocks and waters of the earth, it was little known and little used until quite recently.

J. A. Arfvedson, a young Swedish investigator, in 1817 analyzed a pegmatite rock from an iron mine on the island of Utö, 25 miles southeast of Stockholm. The rock contained spodumene and petalite, and he obtained from it the salt of a new alkali metal. It differed from potassium in that it was not precipitated by tartaric acid and from sodium in that its carbonate was not readily water soluble. He named it "lithium" to signify that it came from a rock.[2]

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[2] Hess, J. L., Lithium: Bureau of Mines Inf. Circ. 7054, 1939, pp. 1-3.

The discovery of spodumene in the United States was first noted in a letter of Thomas Nuttall[3] dated November 22, 1823, in which he announced discovery of the mineral near the town of Sterling, Mass., and said that it had also been found "in a collection of specimens from the vicinity of Deerfield, Mass."

In 1885, Bunsen and Mattheisen succeeded in preparing enough lithium metal for a thorough study. In their investigations they showed that lithium is widely disseminated in minerals, plants, and animal tissues.[4]

On the basis of their work, various investigators studied the element and its compounds. Until recent years most of the small industrial requirements for lithium were supplied from other mineral sources, such as the Searles Lake brines, lepidolite, petalite, etc. However, spodumene has been sporadically mined in the United States, in South Dakota, since 1898.[5] Most of the domestic production of the mineral was from that area until the early 1950's, when the large spodumene pegmatite deposits of the North Carolina area, first worked in the early 1940's, came into extensive exploitation. The raw materials that have permitted increased usage of lithium salts in recent years have been very largely comprised of spodumene concentrates from the Kings Mountain, N. C., area.

OCCURRENCE

The average lithium content of the earth's crust has been estimated at about 0.007 percent.[6] Of some 20 minerals known to contain lithium, only the minerals spodumene, lepidolite, amblygonite, and petalite and the lithium compounds in brines are known to occur in large enough quantities to be produced commercially.

Spodumene usually occurs in, or associated with, pegmatite dikes, with quartz, feldspar, mica, tourmaline, beryl, garnet, lepidolite, etc.[7]

A pegmatite is a rock formed from the solutions expelled from a cooling molten mass of granitoid rock and in its simplest form is an irregular, ocarse-grained rock having the same essential minerals as the granitoid rock to which it is related, but usually having much larger crystals and very unevenly distributed individual minerals. Many pegmatite bodies are elongated and dikelike and may be more than 1,000 feet long and more than 400 feet wide, but most of them are much smaller and may be of any shape.[8]

Spodumene has been found in quantities of commercial significance in South Dakota and in North Carolina. Until recent years the bulk of the spodumene produced in the United States has come from the southern Black Hills of South Dakota. Other and more important deposits occur in an area extending from a point just east of Lincolnton, N. C., southwest to a point near Grover, N. C. This area is roughly 25 miles long, with a maximum width of about 2 miles, and generally is referred to as the Kings Mountain district.[9]

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[3] Journal Philadelphia Academy Natural Sciences, vol. 3, pt. 2, 1824, pp. 284-286.

[4] Work cited in footnote 2, pp. 1-3.

[5] Ladoo, R. B., Non-Metallic Minerals, Occurrence, Preparation, Utilization: McGraw-Hill Book Co., Inc., New York, N. Y., 1925, p. 288.

[6] Lundegardh, P. H., Arkiv. Kemi, Mineral. Geol., 23A, No. 9, 1946.

[7] Ladoo, R. B., and Myers, W. M., Non-Metallic Minerals: McGraw-Hill Book Co., Inc., New York, New York, 1952, pp. 288-294.

[8] Hess, F. L., The Natural History of Pegmatites: Eng. Min. Jour. Press, vol. 120, 1925, pp. 289-298.

[9] Arundale, J. F., Lithium; Mineral Facts and Problems: Bureau of Mines Bull. 556, 1955, pp. 465-470.

Other deposits of spodumene are known in Colorado, Maine, New Mexico, Wyoming, Massachusetts, and Arizona. Crystals of spodumene up to 45 feet long have been found in South Dakota. The spodumene in North Carolina occurs in relatively small crystals, seldom over 2 or 3 feet in length, and most crystals are much smaller.

The approximate composition of the various commercial lithium minerals is shown in table 1.

TABLE 1. - Composition of commercial lithium minerals and compounds[1/]

Mineral	Approximate chemical composition	Range in commercial mineral, percent lithia (Li_2O)
Spodumene	$LiAlSi_2O_6$	4-7
Lepidolite	$K_2Li_3Al_4Si_7O_{21}(OH, F_3)$	3-4
Dilithium-sodium phosphate	Li_2NaPO_4	19-21
Amblygonite	$LiAlFPO_4$	8-9
Petalite	$LiAlSi_4O_{10}$	3.5-4

[1/] Work cited in footnote 9 (p. 466) pp. 465-470.

Spodumene theoretically contains 8.1 percent Li_2O; however, the commercial spodumene normally contains 4 to 7 percent. The variation in lithia content of the commercial minerals as mined is due to replacement of the lithia by soda and potash, to partial alteration of the mineral to nonlithium minerals, and to the presence of impurities.

The Physical Services Section of the Southern Experiment Station, Bureau of Mines, analyzed the spodumene crystals. The principal objective was to determine the actual lithia contents and the various minor constituents of spodumene crystals from various deposits. The following procedure was used:

1. Spodumene crystals were hand-picked from the various ores.
2. Crystals were crushed and ground to minus-200-mesh to liberate any impurities in the crystals.
3. The ground samples were separated by high-speed centrifuging at 2.94 specific gravity, with acetylene tetrabromide as the separating medium.
4. The sink fraction in 2.94 specific gravity was examined petrographically to determine purity of the product.
5. Products were analyzed with the flame spectrophotometer to determine lithia content.

Samples of the hand-picked spodumene crystals were analyzed before and after separation at a specific gravity of 2.94. Results of petrographic and chemical analyses indicate that all the spodumene crystals contain inclusions of quartz and other impurities within the crystals. Even after separation at a specific gravity of 2.94, the samples contain minor quantities of entrapped quartz.

Results of complete analyses of various spodumene crystals are shown in table 2.

TABLE 2. - Analyses of spodumene crystals

		Chemical analysis, percent						
		Li_2O	Al_2O_3	SiO_2	K	Na	Acid-soluble Fe_2O_3	Total Fe_2O_3
Kings Mountain, N. C.	1/	7.07	28.0	62.1	0.09	1.20	0.17	0.67
	2/	7.76	28.6	61.7	.05	.85	.13	.62
Beaver Dam Creek (near Lincolnton, N. C.)	1/	7.46	28.2	60.3	.09	1.16	.70	2.01
	2/	7.70	28.9	60.2	.07	1.01	.10	1.05
Hill City, S. Dak.	1/	7.50	27.1	61.0	.15	2.27	.28	1.31
	2/	7.62	29.5	60.2	.09	1.17	.11	.52
Quebec, Canada	1/	6.85	26.1	61.2	.16	2.30	1.17	2.66
	2/	7.96	26.6	60.2	.09	1.83	.09	2.05

		Qualitative spectrographic analysis, percent								
		Be	CaO	MnO	Rb	Sn	Zr	Ti	Mg	Cu
Kings Mountain, N. C.	1/	0.0049	0.2	0.1	Trace	0.01	0.01	0.02	0.002	Trace
	2/	Below .0016	.2	.1	do.	.01	.01	.02	.002	Do.
Beaver Dam Creek (near Lincolnton, N. C.)	1/	.0055	.2	.1	do.	.01	.01	.02	.002	Do.
	2/	Below .0016	.2	.1	do.	.01	.01	.02	.002	Do.
Hill City, S. Dak.	1/	.0021	.2	.1	do.	.01	.01	.02	.002	Do.
	2/	Below .0016	.2	.1	do.	.01	.01	.02	.002	Do.
Quebec, Canada	1/	Below .0016	.2	.1	do.	.01	.01	.02	.002	Do.
	2/	Below .0016	.2	.1	do.	.01	.01	.02	.002	Do.

1/ Hand-picked crystal, crushed and analyzed without treatment.

2/ Hand-picked crystal, crushed and separated at 2.94 specific gravity to remove any free quartz within the crystal.

MINERALOGY[10]

Spodumene occurs in distinct, prismatic, characteristically large crystals with a nearly square, rounded, or tabular cross section. The commercial mineral is a dull gray-white or yellow. Transparent colored varieties, such as triphane (yellow), hiddenite (green), and kunzite (purple), are used as gems. The hardness of the fresh mineral is 6.5 to 7.0, and its specific gravity is about 3.17. Spodumene is a monoclinic pyroxene, the prismatic cleavage angle being about 93 degrees. Spodumene colors the blowpipe flame crimson, as do all the lithium minerals.

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[10] Mumford, R. W., Lithium Minerals: Ind. Minerals and Rocks, AIME, New York, 2d ed., 1949, pp. 513-520.

RESERVES

United States

Measured reserves of spodumene appear to be relatively small when compared to potential future demand. However, the Geological Survey[11] reports that there are indicated domestic spodumene reserves of 5 million units (a unit being 1 percent of 1 short ton or 20 pounds) and inferred reserves of 124 million units of lithia. This appears to be adequate to sustain the industry at the present rate of consumption for many years.

A large part of the known spodumene reserve in the United States is in the pegmatite belt near Kings Mountain, N. C., where several hundred spodumene-bearing pegmatites have been identified. Spodumene is the major lithium-bearing constituent of these pegmatites, and amblygonite has been recognized as an accessory mineral. The estimated lithia content of indicated reserves in the district is about 4 million units of ore averaging 1.7 percent lithia and about 124 million units in ore averaging 1.3 percent lithia.

Foote Mineral Co.[12] is reported to have about 24 million tons of commercially minable spodumene ore. These reserves can be expected to support the organization's refining operations at foreseeable rates for at least 50 years.

Basic Atomics, Inc., of Lincolnton, N. C., claims spodumene reserves of 11 million tons in Lincoln County.[13]

During 1956, about 15 companies were actively exploring in the Kings Mountain district. These companies have developed additional millions of tons of minable spodumene ore.

Known deposits in the Black Hills of South Dakota probably contain over 1 million units of lithia. Spodumene is the dominant lithium mineral in nearly all the deposits and constitutes 85 percent of the known lithium reserve of the area. The accessory lithium minerals are lepidolite, amblygonite, and petalite.

Small spodumene deposits are known in Arizona, New Mexico, Colorado, Wyoming, and New England.

Canada

Recent intensive exploration in Canada has revealed many pegmatites containing millions of tons of spodumene ore.[14] Important reserves have been developed in the Provinces of Quebec, Manitoba, Ontario and in the Northwest Territories.

For example, Quebec Lithium Corp. reports development of 15 million tons of 1.3-percent lithia ore at its property north of Val d'Or, Quebec.[15]

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[11] Norton, J. J., and Schlegel, D. M., Lithium Resources of North America: Geol. Survey Bull. 1027-G, 1955, pp. 325-350.

[12] Mining Record, May 24, 1956, vol. 67, No. 21, p. 3.

[13] Engineering and Mining Journal, vol. 157, No. 7, July 1956, p. 73.

[14] Work cited in footnote 12 (p. 348), 25 pp.

[15] Canada Department of Mines and Technical Surveys, Lithium Minerals 1955 (Preliminary): No. 13, 7 pp.

MINING

Ordinary quarrying methods are employed in mining many unweathered pegmatite dikes, even in some places where relatively large quantities of barren rock must be handled to permit recovery of marketable minerals. Stripping methods have found increased favor during recent years, both for removing overburden from gently dipping deposits and for eliminating dangerously steep or overhanging walls of cuts. Highly mechanized techniques, involving the use of dragline scrapers, bulldozers, and power shovels, have proved effective at several deeply weathered deposits.16/

One of the largest spodumene-bearing operations is that of the Foote Mineral Co. at Kings Mountain, N. C. The deposit being mined is a dike with a maximum width of 300 feet and length exceeding 1,000 feet. Because of the topography, it was possible to develop a face 200 feet long by clearing the trees and making a road along the footwall. Mining is carried on simultaneously with stripping operations. The top 6 to 8 feet is being wasted, as it contains most of the dirt and clay so detrimental to the milling operations. The shovel operator loading ore for the crusher sorts it to remove as much of the waste as possible. Future development will, of course, depend upon the character of the dikes being worked. At present there are no plans for any underground operations, as there is at least a 10-year reserve of ore for surface mining. In the future, ore bodies will be developed by stripping the eastern footwall to give a 30-foot roadway, with a slope of about 1 to 1 in the discarded waste. The face will then be carried across the strike of the dike, and the hanging wall sloped at whatever angle is necessary for safety. This will give a safer operation and also make it possible to recover some ore from small dikes that lie close to the large ore bodies.17/

The Lithium Corp. of America, at Bessemer City, N. C., has reserves that in the future probably will be mined by a similar system. At present it is not mining in the North Carolina district but is operating entirely on Canadian concentrates.

Maywood Chemical Works operates the Etta mine in South Dakota by a "gloryhole" system. The spodumene occurs in large crystals and is amenable to hand picking.

Quebec Lithium Corp. of Val d'Or, Quebec, Canada, is currently mining about 1,000 tons per day by shrinkage-stope methods.

CONCENTRATION

Spodumene is recovered from its ores by hand picking, flotation, and heavy-medium separation. All processes are relatively inefficient, as 60- to 70-percent lithia recovery is probably the best that is accomplished in actual practice. Because of the losses in concentration, increased emphasis in research is being placed on new and improved processes. In part, the losses are due to the fact that 15 to 20 percent of the lithia content of the ores is present in clays or micas.

Until recent years a major part of domestic spodumene production was accomplished by hand picking. This method is limited to deposits where the spodumene-crystal aggregates are large enough to be readily seen and separated. The Etta mine

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16/ Jahns, R. H., Geology, Mining and Uses of Strategic Pegmatites: Min. Eng., vol. 190, No. 1, 1951, pp. 45-59.

17/ Goter, E. R., Rainey, D. L., and Hudspeth, W. R., Mining and Milling of Lithium Pegmatites at Kings Mountain, N. C.: Min. Eng., vol. 5, No. 9, 1953, pp. 890-893.

of the Maywood Chemical Works in South Dakota is the only operation now utilizing hand picking.[18]

The successful flotation of nonmetallic minerals led to trials of lithium minerals, notably spodumene. The Bureau of Mines cooperated with several companies in developing concentration methods.

Most major lithium companies now utilize froth flotation to recover spodumene values. Flotation methods are effective for concentrating such ores but require expensive grinding through 40 or 60 mesh. The fine grind, however, tends to produce mineral slimes, causing loss of a small part of the lithium.

Until recently, the Lithium Corp. of America operated a flotation mill near Hill City, S. Dak., but the mill was shut down and placed on a standby basis in January 1956. However, in order to illustrate the type of flowsheet utilized in spodumene flotation, the flow diagram of the mill is shown in figure 1.[19]

Foote Mineral Co. began production of spodumene concentrates at its Kings Mountain, N. C., plant in 1951.[20] Since that time the capacity of the plant has been greatly increased and now includes heavy-medium separation as well as flotation.

Quebec Lithium Corp. began production in November 1955 at its plant at Val d'Or, Quebec.[21] The plant has a rated capacity of 1,000 tons of ore per day. The ore is mined underground by shrinkage-stoping methods. Coarse crushing is done underground, and the crushed ore is hoisted to a 1,000-ton bin at the headframe. From there it is conveyed to the crusher house for primary and secondary crushing before storage in 2 fine-ore bins with a total capacity of 2,500 tons. In the mill the ore is ground to pass 20-mesh in a rod mill. Cyclones and Dorr hydrosizers are used for classification. Two banks of flotation cells are used for flotation of the spodumene in an acid circuit. Total mining and milling costs are reported to be about $5.00 a ton.

EXTRACTION

Two methods are normally employed to recover lithium compounds from spodumene; one is an acid, the other an alkali treatment. In the first method alpha spodumene is converted to beta spodumene by calcining to the inversion temperature in a kiln. Sulfuric acid is added, and this mixture is then heated to form lithium sulfate. The pH is adjusted with limestone, and the lithium sulfate is leached from the mass and filtered. Soda ash is added to the solution of lithium sulfate to precipitate lithium carbonate. This is the basic material from which other lithium compounds are derived.[22]

The flowsheet showing the derivation of lithium compounds from spodumene by the acid-leach process (as shown in fig. 2) was adapted from the February 1956 issue of

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[18] Work cited in footnote 9 (p. 3), 6 pp.

[19] Runke, S. M., Binyon, E. O., and Cunningham, J. B., Progress Report on Pegmatite Investigations in South Dakota: Bureau of Mines Rept. of Investigations 5061, 1954, 21 pp.

[20] Foote Prints, vol. 26, No. 2, 1954, pp. 4-6.

[21] The Northern Miner, vol. 41, No. 32, pp. 1 and 8.

[22] Work cited in footnote 8 (p. 294), pp. 289-298.

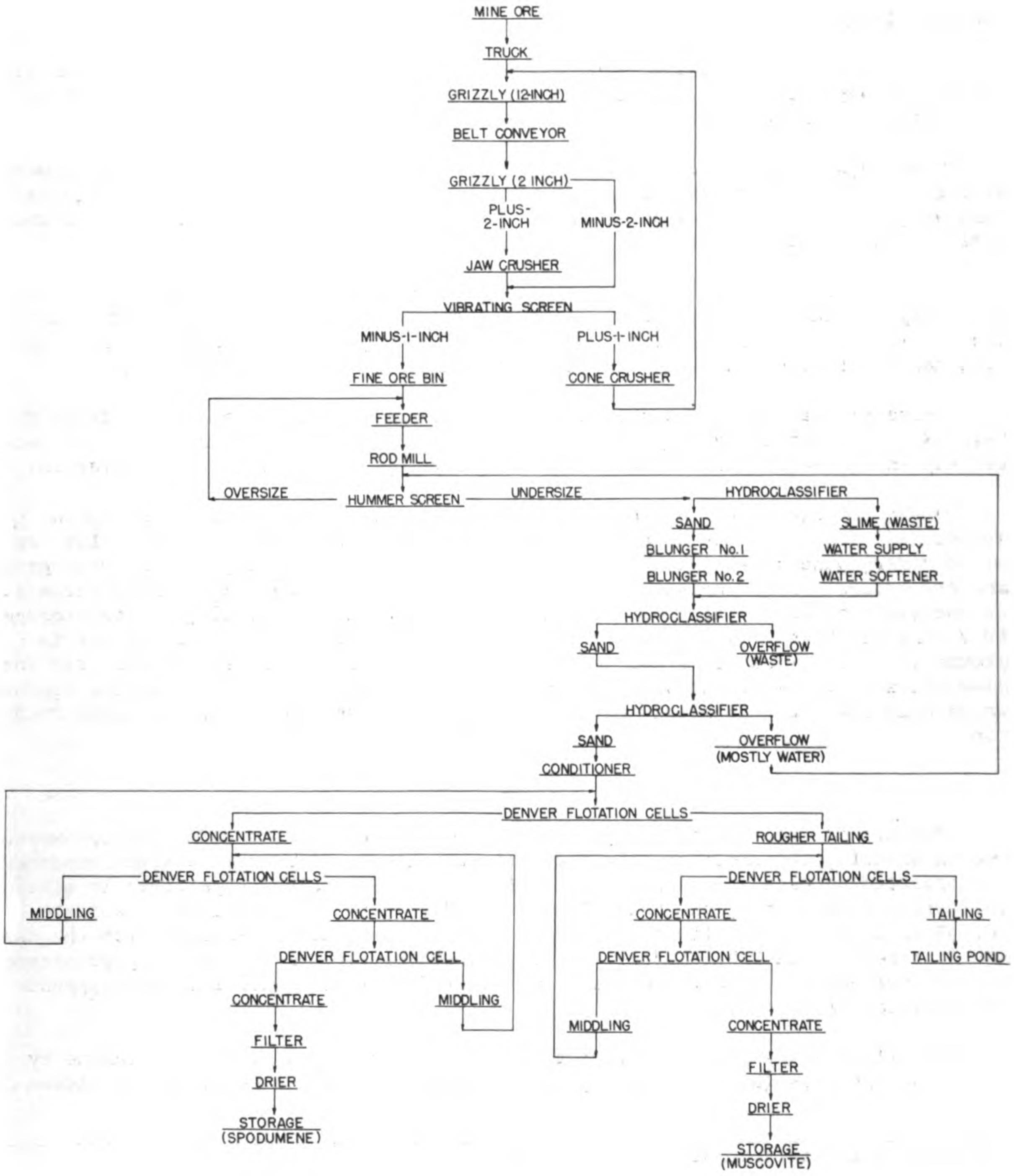

Figure 1. - Flowsheet of concentrating plant, Lithium Corp. of America, Hill City, S. Dak.

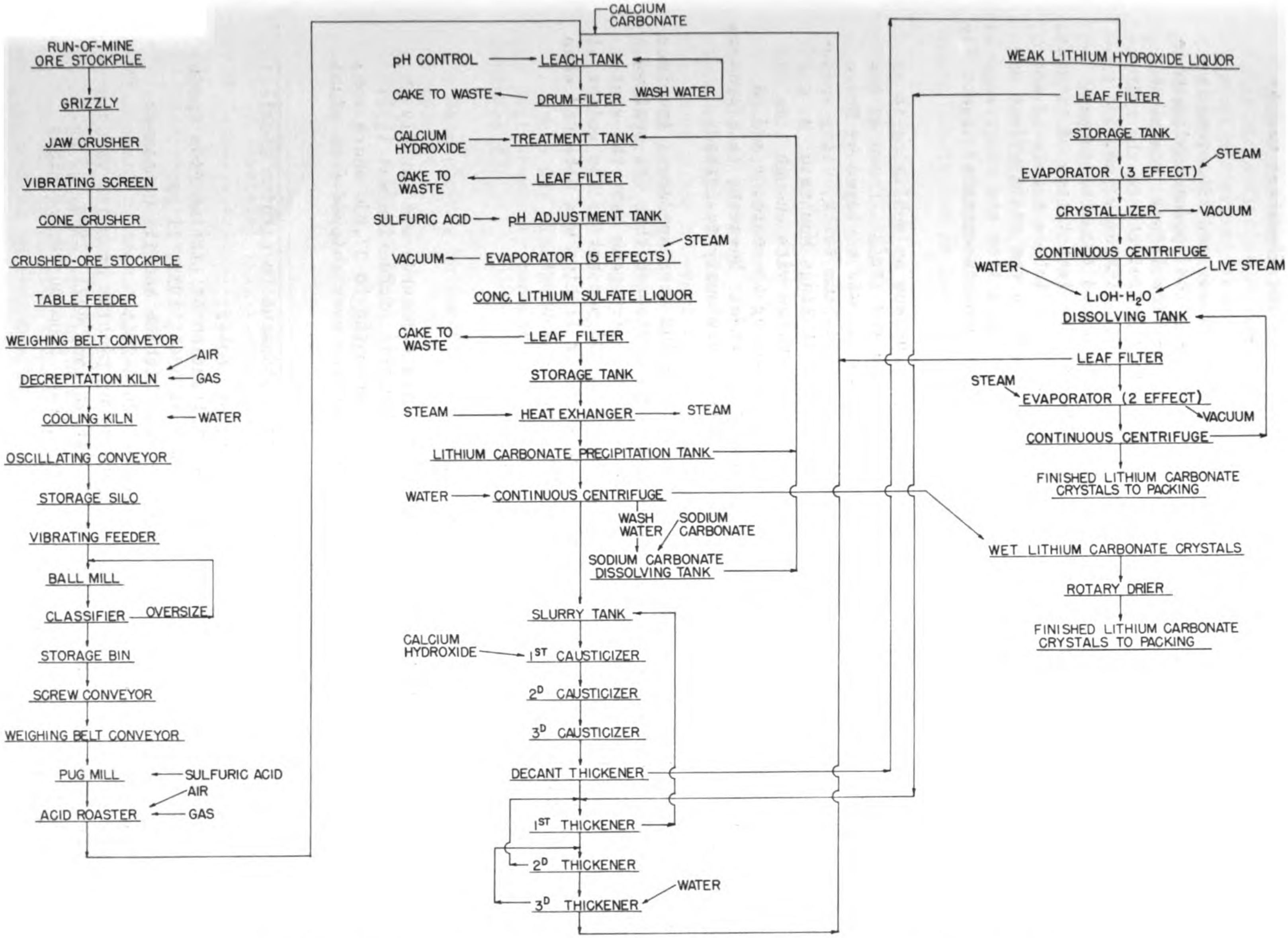

Figure 2. - Flowsheet for converting spodumene to lithium chemicals, Lithium Corp. of America, Bessemer City, N. C.

the Mining World by permission of the editors.[23] This is the flowsheet used by Lithium Corp. of America at its Bessemer City, N. C., plant.

In the Alkaline-leach process a slurry of ground spodumene and limestone is roasted in a rotary kiln at about 1,900° F. After roasting the spodumene-limestone mixture is pulverized and slurried by the addition of overflow liquor from subsequent thickening operations. Calcium oxide in the slurry hydrolyzes to the hydroxide and reacts with lithia to leach out lithium hydroxide. Lithium values are concentrated in solution by a series of thickeners, and separated from the gangue, which is discarded after washing and filtering to remove the last traces of lithium. Strong liquor from the thickeners is passed through a filter into a triple-effect evaporator. Lithium hydroxide monohydrate is crystallized in the third effect and reocvered as a crystalline product by centrifugation. Liquid from the centrifuge is evaporated further and filtered to yield additional LiOH and concentrated liquor for recycle.[24]

An ankaline process for recovering lithium from spodumene by subliming it as the chloride attained commercial importance during World War II.[25] Known as the Bureau of Mines method, the chloride-volatilization process was employed by Foote Mineral Co. and others in the large-scale production of lithium salts, using spodumene produced in large quantities by Solvay Process Co. at Kings Mountain, N. C.[26] In the chloride-volatilization process the spodumene is mixed with enough lime and calcium chloride to displace the lithium in the spodumene by the calcium and to supply enough available chlorine to produce lithium chloride. However, this process is now obsolete and has been replaced by the processes previously described.

Another Bureau of Mines process for extracting lithium from spodumene involves sintering with gypsum and lime.[27] Experimental study indicated that the optimum proportions of gypsum and lime were a 100-percent excess of gypsum over the stoichiometric amount and an amount of lime equal to 75 to 100 percent of the weight of the mineral treated. Recovery of 80 to 85 percent of the lithium was obtained when the mixture was sintered at 1,050° to 1,150° C. for 1 to 2 hours.

PRODUCTION

United States

The wide commercial application of lithium and its compounds was largely an outgrowth of World War II. The 1935-39 (average) domestic production was 1,327 short tons of ore. In 1954 the domestic production amounted to 37,830 short tons of lithium minerals, up to that date the largest quantity ever shipped from mines in the United States in a single year.[28]

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[23] Mining World, How Lithium Corporation Converts Spodumene to Lithium Chemicals: Vol. 18, No. 2, 1956, pp. 57-59 and 91.

[24] Chemical Week, vol. 78, No. 5, Feb. 11, 1956, pp. 60-62.

[25] Fraas, F., and Ralston, O. C., Chloride Volatilization of Lithium From Spodumene: Bureau of Mines Rept. of Investigations 3344, 1937, 11 pp.

[26] Hader, R. N., Nielson, R. L., and Herre, M. G., Lithium and Its Compounds: Ind. Eng. Chem., vol. 43, No. 12, 1951, pp. 2636-2645.

[27] Cunningham, J. B., and Gorski, C. H., Recovery of Lithium From Its Various Ores and Salts: Bureau of Mines Rept. of Investigations 4321, 1948, 35 pp.

[28] Arundale, J. C., and Marks, A. L., Lithium: Prep. from Bureau of Mines Minerals Yearbook, 1954, p. 2.

The Foote Mineral Co. has completed expansion of its spodumene mining and beneficiation facilities at Kings Mountain, N. C., and an increase in capacity of the chemical processing plant at Sunbright, Va. Sunbright's capacity will be increased from about 4 million pounds a year (expressed as lithium hydroxide) to 10 million pounds. The company's Exton, Pa., facilities have an annual capacity of 2 million pounds, bringing Foote's total capacity to 12 million pounds annually.[29]

Lithium Corp. of America produces lithium chemicals at an integrated lithium-refining plant at Bessemer City, N. C., using spodumene concentrates produced by Quebec Lithium Corp. in Quebec, Canada. Lithium compounds and metal are also produced in the company plant at St. Louis Park, Minn.[30] Potential production figures for this operation are not available.

Maywood Chemical Works is a major producer of lithium compounds, with mines in South Dakota and an integrated processing plant in Maywood, N. J.

Midwest Lithium Corp. announced that the first complete lithium-processing plant in the Black Hills will be in operation sometime in 1957.[31] The company plans to process lithium in the old U. S. Gypsum Co. plant near Piedmont, S. Dak.

Canada

Quebec Lithium Corp. has constructed a milling plant near Barraute, Quebec. The mill is designed for a capacity of 1,000 tons per day and began operating in November 1955. Spodumene reserves totaling 15 million tons have been outlined. The company has a 5-year contract for selling 165 tons of spodumene concentrates daily to Lithium Corp. of America at a reported price of $11 per unit. At the indicated grade of 1.2 percent lithia, this would mean a gross value of $13.20 per ton of ore. The company expects to recover at least 75 percent of the lithia and yield a profit of $5.00 per ton of ore.[32]

Green Bay Mining & Exploration Ltd., Edmonton, Canada, plans to erect a 1,000-ton-daily-capacity concentrator for processing lithium ore in the Herb Lake area in Manitoba.[33]

Data showing shipment of lithium ores from mines in the United States are shown in table 3.

TABLE 3. - Shipments of lithium ores and compounds from mines in the United States, 1935-39 (average), 1945-49 (average), and 1950-54[34]

Year	Ore (short tons)	Value	Li_2O (short tons)
1935-39 (average)	1,327	$ 48,280	88
1945-49 (average)	3,334	259,457	312
1950	9,306	579,922	747
1951	12,897	896,000	956
1952	15,611	1,052,000	1,088
1953	27,240	2,134,000	1,767
1954	37,830	3,126,000	2,459

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[29] Chemical Engineering News, vol. 33, No. 13, Mar. 28, 1955, p. 1269.
[30] Stephenson, R. C., Lithium: Min. Eng., vol. 7, No. 3, 1955, p. 273.
[31] The Mining Record, vol. 67, No. 3, Jan. 19, 1956, p. 7.
[32] Work cited in footnote 21 (p. 1), pp. 1 and 8.
[33] Oil, Paint and Drug Reporter, vol. 169, No. 25, June 18, 1956, p. 53.
[34] Work cited in footnote 27 (p. 2), pp. 2 and 3.

CONSUMPTION AND USES[35]

The two largest uses of lithium compounds, namely, in the production of ceramics and greases, are rapidly increasing. It has been estimated that approximately 15 percent of the lubricating grease manufactured contains lithium. This application presents a large and growing market. Another large use of both lithium minerals and compounds is in the manufacture of ceramics, such as glass, glazes for sanitary ware and whiteware, and vitreous enamels for metals.

TABLE 4. - Estimated end use of lithium compounds[1]

End use	Thousand pounds, in terms of carbonate 1951	Thousand pounds, in terms of carbonate 1955 (estimated)
Pharmaceuticals	33	200
Alkaline storage batteries	393	550
Air conditioning and refrigeration	320	450
Lubricating grease	816	3,500
Aluminum welding and brazing	287	750
Ceramics	779	3,500
Defense and miscellaneous	393	-
Total	3,021	8,950

[1] Engineering and Mining Journal, vol. 156, No. 9, September 1955, p. 83.

TABLE 5. - Lithium concentrate prices[1] f.o.b. mine (subject to negotiation)

Spodumene, 6 percent Li_2O	$11-12 per short-ton unit
Lepidolite, hand-picked	11-12 per short-ton unit
Petalite, hand-picked	11 per short-ton unit
Amblygonite	60-75 per short-ton

[1] Engineering and Mining Journal, Metal and Mineral Markets, Sept. 1, 1955, p. 7.

An important use of lithium compounds is in Edison nickel-iron alkaline storage batteries. These cells are used in batteries for electric industrial trucks, mine locomotives, and portable lighting equipment.

Lithium chloride is one of the most hygroscopic of all inorganic compounds and because of this property is utilized in air conditioning and industrial drying.

Lithium fluoride and chloride are used as oxide scavengers and metal cleaners in welding or brazing aluminum and magnesium.

Lithium compounds are also used in organic synthesis, medicinals, and cosmetics. In copper processing they are used to produce dense, oxygen-free, high-conductivity type metal, as well as in various metal heat treatments of castings, and powder metallurgical processes.

In addition, there are several direct military uses for various lithium products.

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[35] Work cited in footnote 28, pp. 2 and 3.

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The estimated end uses of lithium are shown in table 4.

Potential Consumption and Uses

At the request of the Defense Department the Materials Advisory Board of the National Academy of Sciences conducted a study on lithium.[36] The availability and potential use of lithium were studied. This report indicates that three factors will expand the utilization of lithium and its compounds: (1) lower price, (2) assured availability, and (3) research and development. The ceramics field provides the most immediate growth potential for lithium consumption, estimated at 2 to 12 million pounds per year. The use of lithium hypochlorite as a dry household bleach offers an estimated consumption potential of 10 million pounds a year, provided the price handicap can be surmounted. The use of lithium in all-purpose greases has an estimated growth potential of 2 to 7 million pounds per year. A research program for developing uses for lithium and its compounds should cover the following fields: Ceramics, metallurgy, biochemical processes, energy sources (such as propellants), organic syntheses, controlled nuclear reactions, improved extraction and production methods, and petroleum.

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[36] Materials Advisory Board, National Research Council, Lithium: Washington, D. C., Rept. MAB-88-M, June 15, 1955, 17 pp.

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